Risk and Uncertainty in Asset Management

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Relevance of *Risk* to Asset Management

- Campaign Plan Objective 3C:
  - "Improve the reliability of water resources infrastructure using a risk based asset management approach…"
- What is risk-based asset management?

Outcomes from Aug 05 Workshop

- **Asset management,** as defined by the panel experts and participants at the workshop:

"A way to manage resources that will maximize life cycle performance, minimize risk, and optimize our infrastructure for the good of the nation."

Outcomes from Aug 05 Workshop

- The top 5 **critical problems** identified and prioritized by the group were:
  1) lack of standards and criteria,
  2) condition assessment,
  3) risk and uncertainty,
  4) business line processes and
  5) inadequate models and tools.

Risk Defined

Risk: The likelihood or probability of an adverse outcome

- Examples
  - Being hit by a car while taking a walk
  - Structural failure of a dam
  - Breaching of a levee during a flood
  - Reduced performance of a lock measured in terms of tow transits per day
- For use in decision making, event probability is combined with a description of consequences

Uncertainty Defined

Uncertainty: Lack of confidence in an analysis, assessment, prediction, inference or conclusion

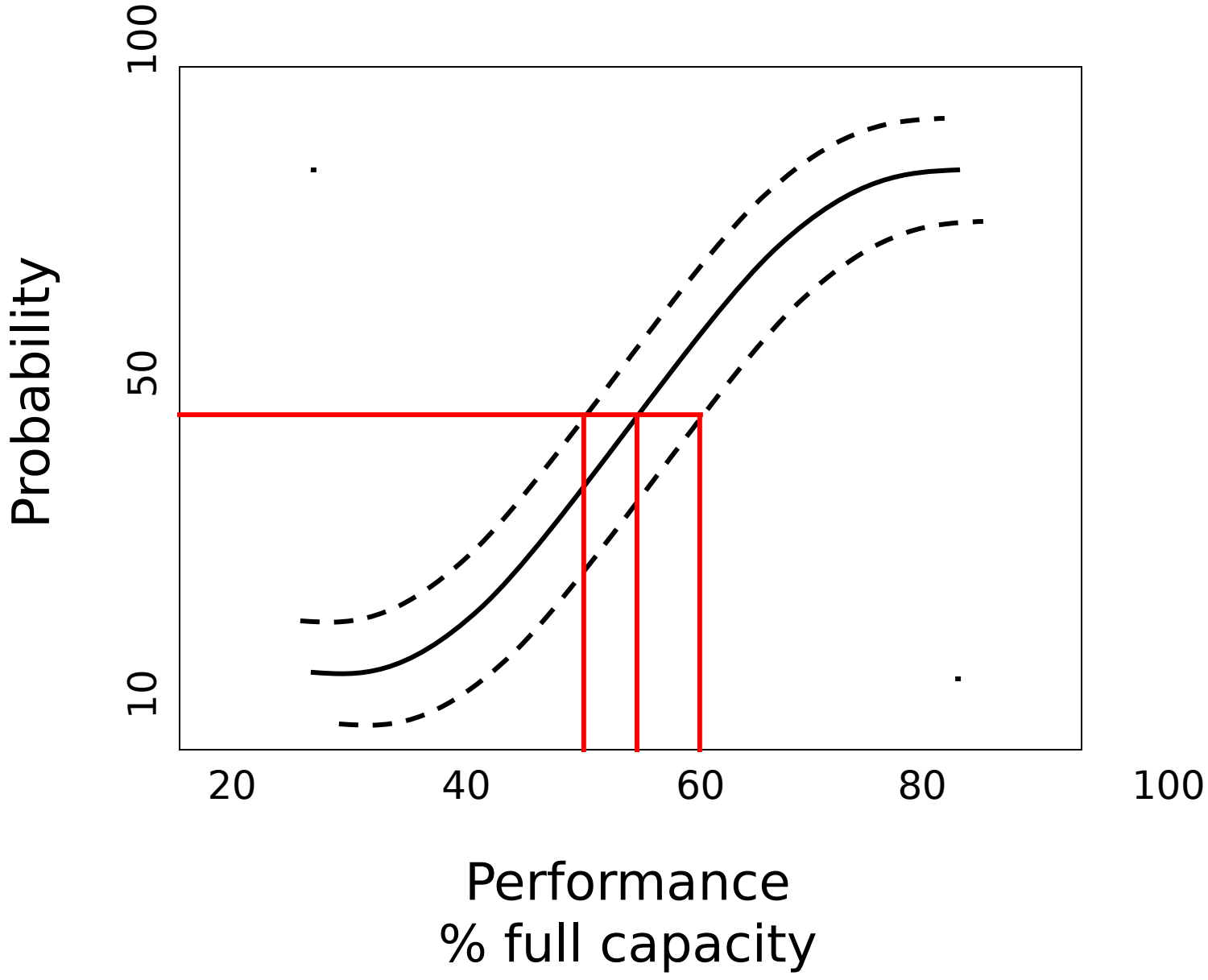
- An important distinction:
  - Making a prediction and
  - Attaching a measure of confidence to that prediction

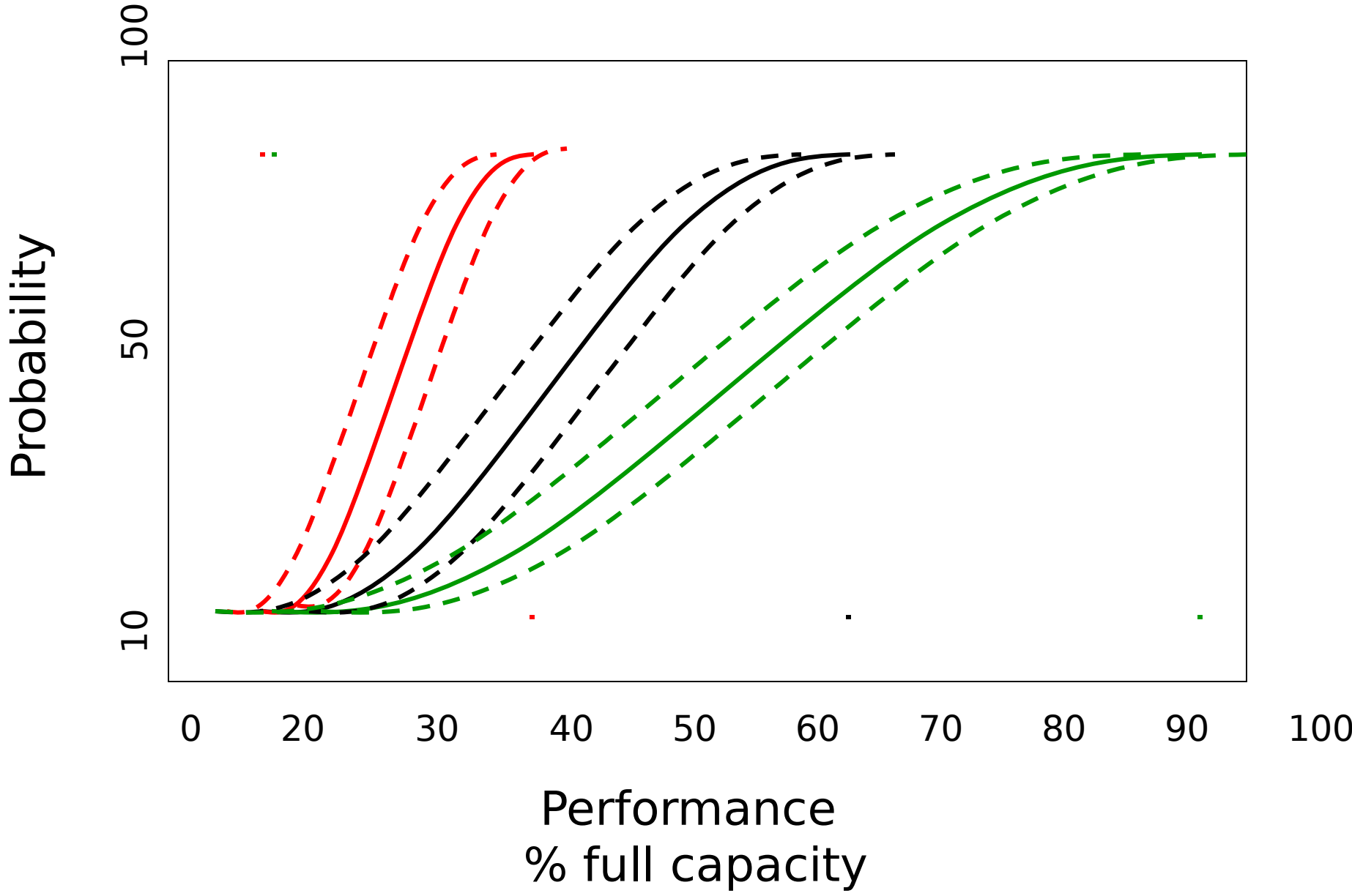
Practical Sources of Uncertainty

- Scenario
  - Missing components in the Conceptual Model
  - e.g., failure to consider specific threat scenarios
- Model
  - Structure and assumptions differ among models
  - e.g., choices about use of specific models (hydrodynamic codes, structural failure)
- Parameter
  - Specification of model parameters
  - e.g., bottom roughness parameter in a hydrodynamic model

Nature of Uncertainty

- Natural variability
  - Known population heterogeneity
  - Cannot be reduced only characterized
- Epistemic uncertainty
  - Lack of knowledge or understanding
  - Can collect more data/information


Probability
100
50
10
20
40
60
80
100
Performance
% full capacity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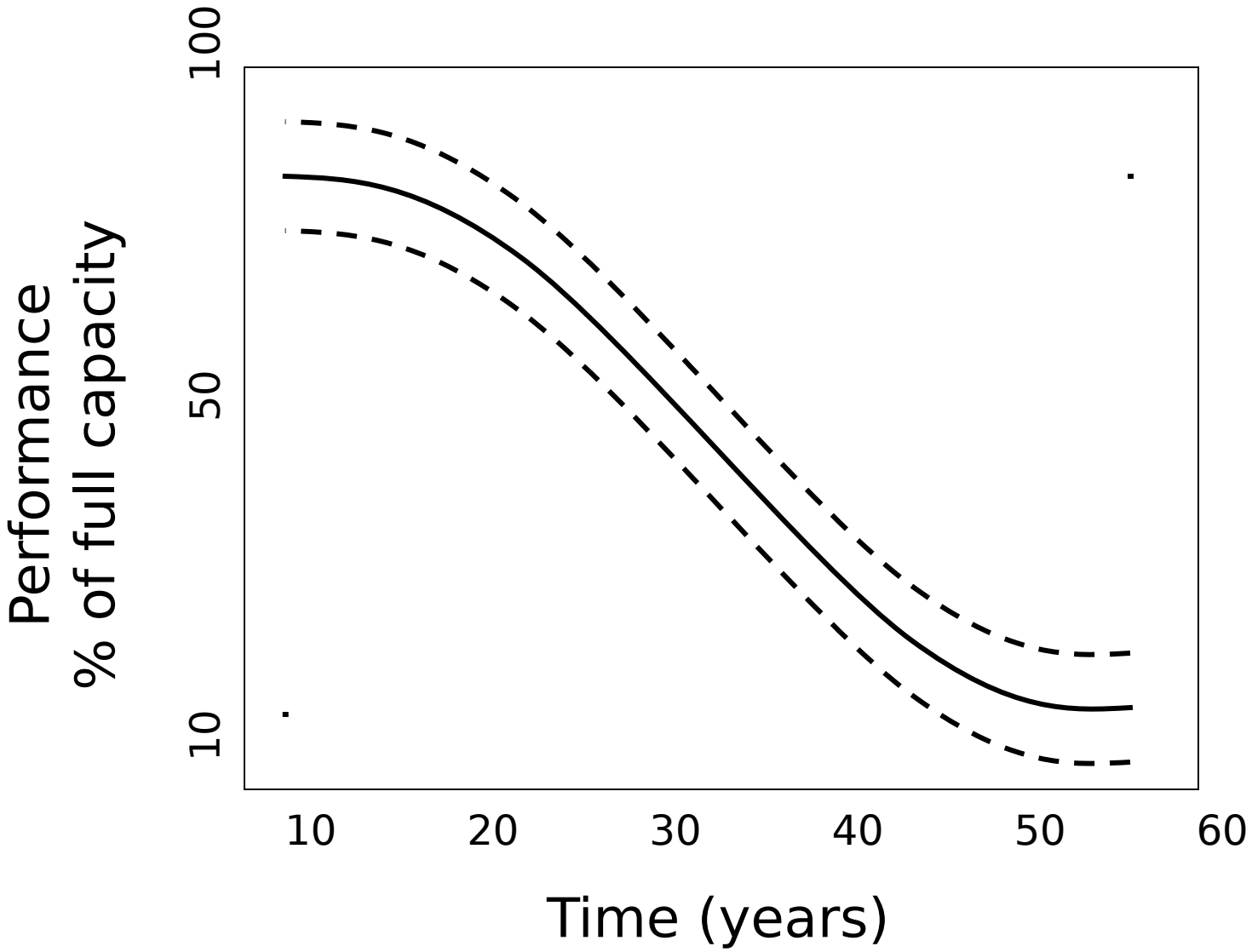
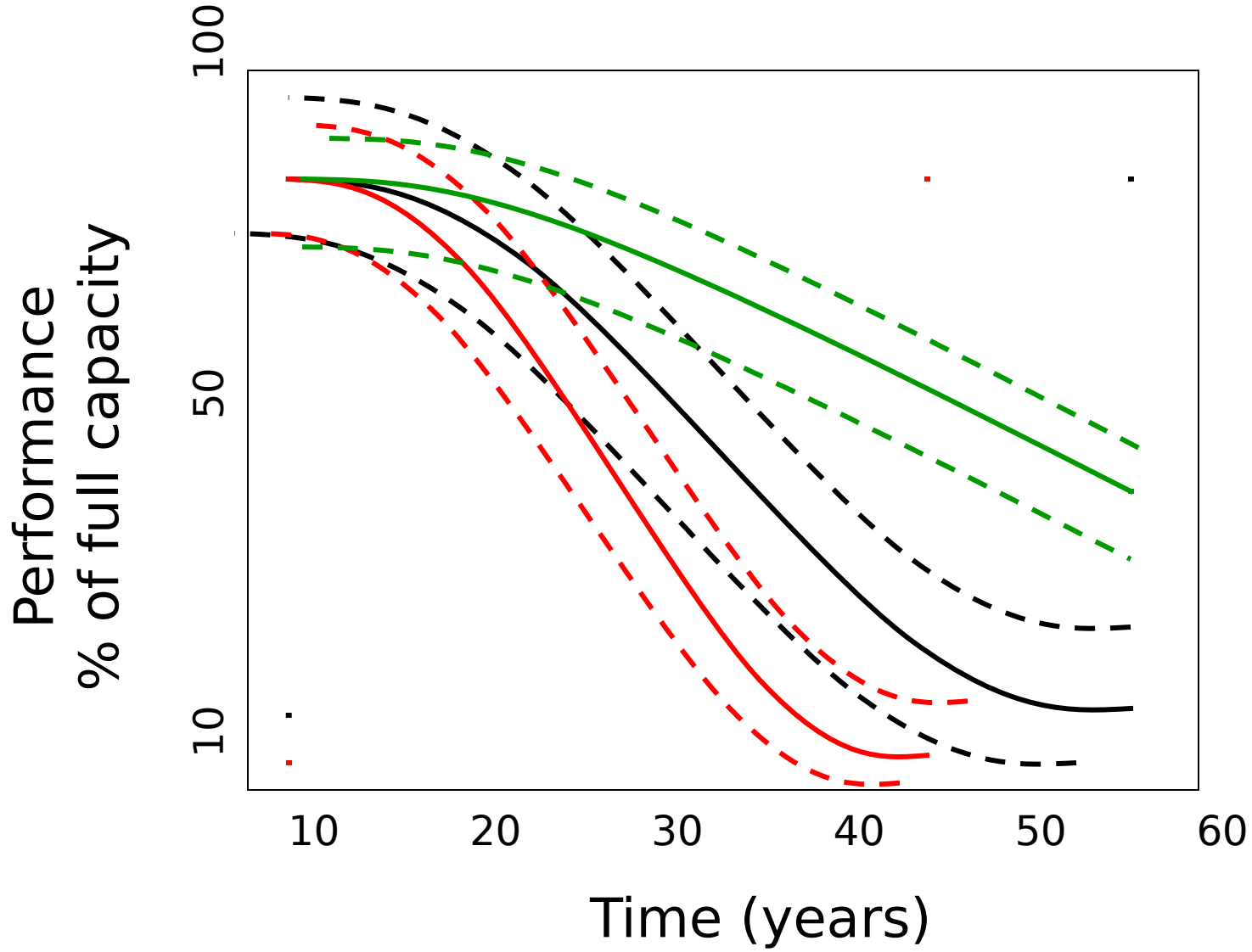

Performance
% of full capacity
100
50
10
10
20
30
40
50
60
Time (years)


Performance
% of full capacity
100
50
10
10
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40
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60
Time (years)

Risk-Based Decision-Making

- *Risk assessment*: A process for developing a quantitative understanding of the processes shaping the scope and nature of risks and uncertainties that is sufficient to support decision making
  - What is the risk?
  - Why and how are the risks occurring?
  - What is the uncertainty associated with the risk estimate?
  - How do the management alternatives differ in terms of risk reduction performance?

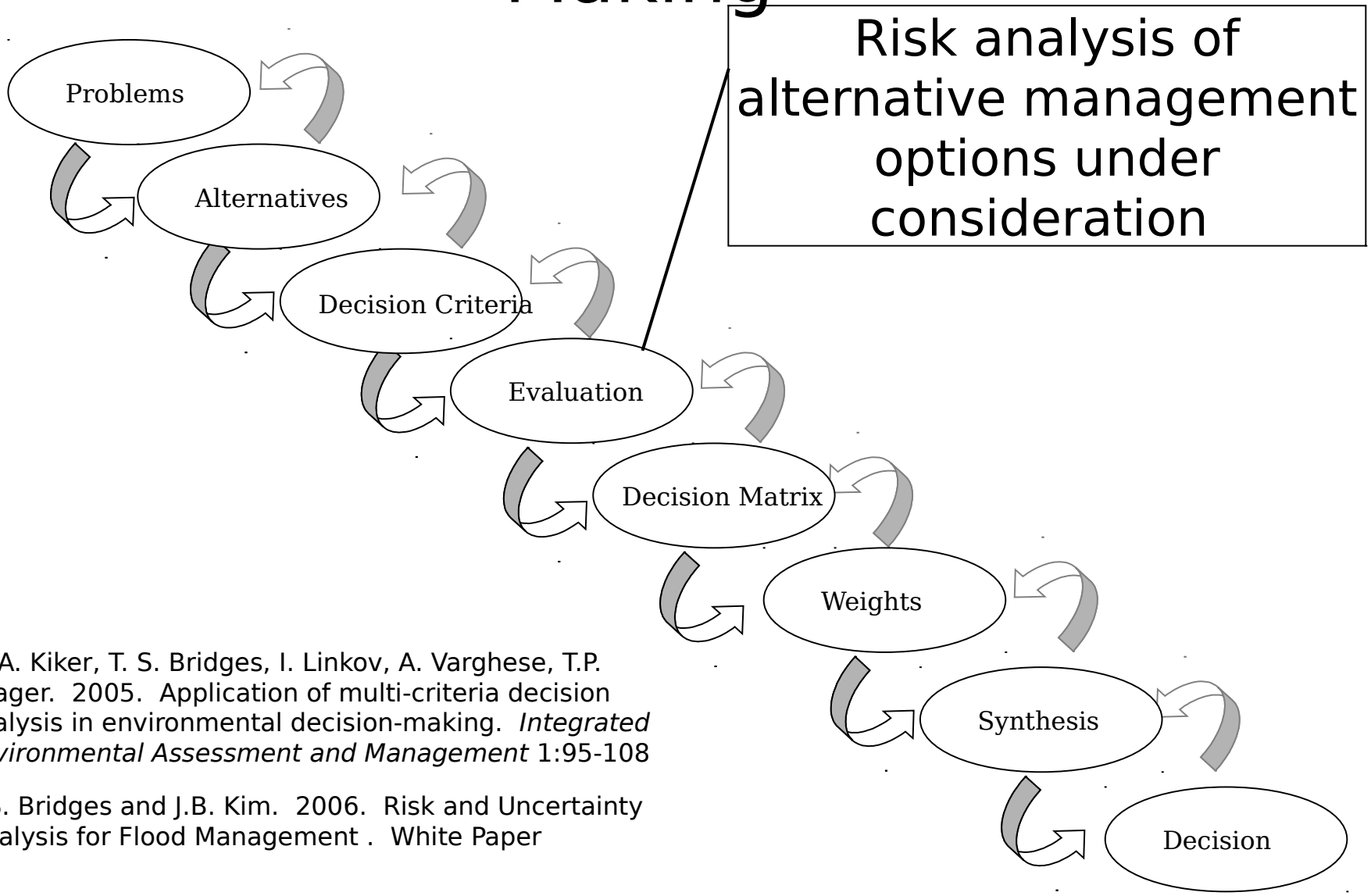
Risk-Based Decision-Making

- *Risk management*: Actions taken to reduce risks to acceptable levels and manage uncertainties in a manner that is informed by facts about the risks
  - How do I balance the trade-offs inherent to decision making?
  - How do I apply the rules of decision-making in a consistent and transparent way?
  - How do I develop an understanding of the influence of values in my decision?

Distinguishing Risk Assessment from Risk Management

- As a general rule, the technical analysis of risks should be distinguished/separated from the decision process concerned with what to do about those risks
  - Risk Assessment should be dominated by science and engineering
  - Risk Management will and should involve policy, the use of values, and trade-offs

A Process for Structured Decision-Making



G. A. Kiker, T. S. Bridges, I. Linkov, A. Varghese, T.P. Seager. 2005. Application of multi-criteria decision analysis in environmental decision-making. *Integrated Environmental Assessment and Management* 1:95-108

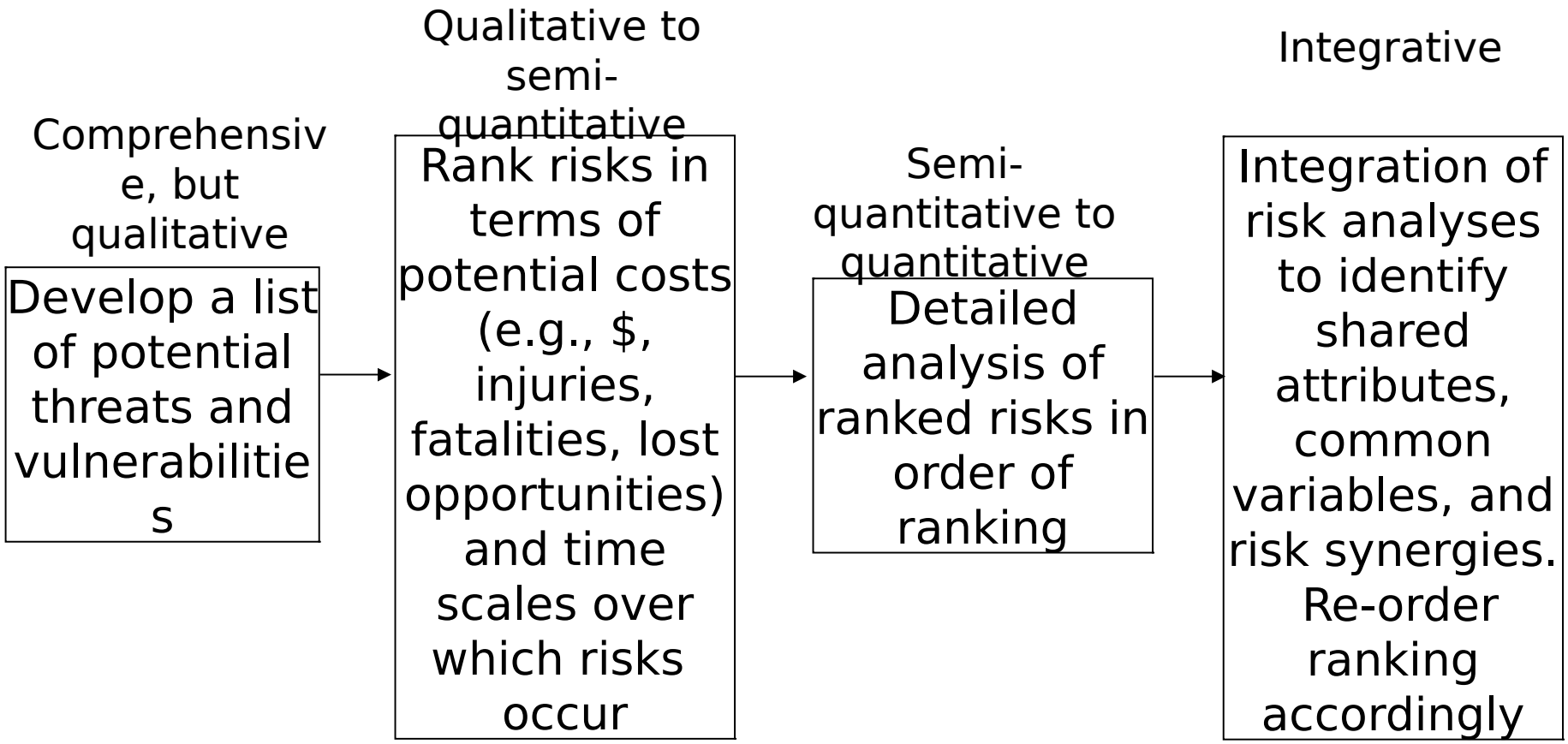
T.S. Bridges and J.B. Kim. 2006. Risk and Uncertainty Analysis for Flood Management . White Paper

Adapted from Yoe (2002)

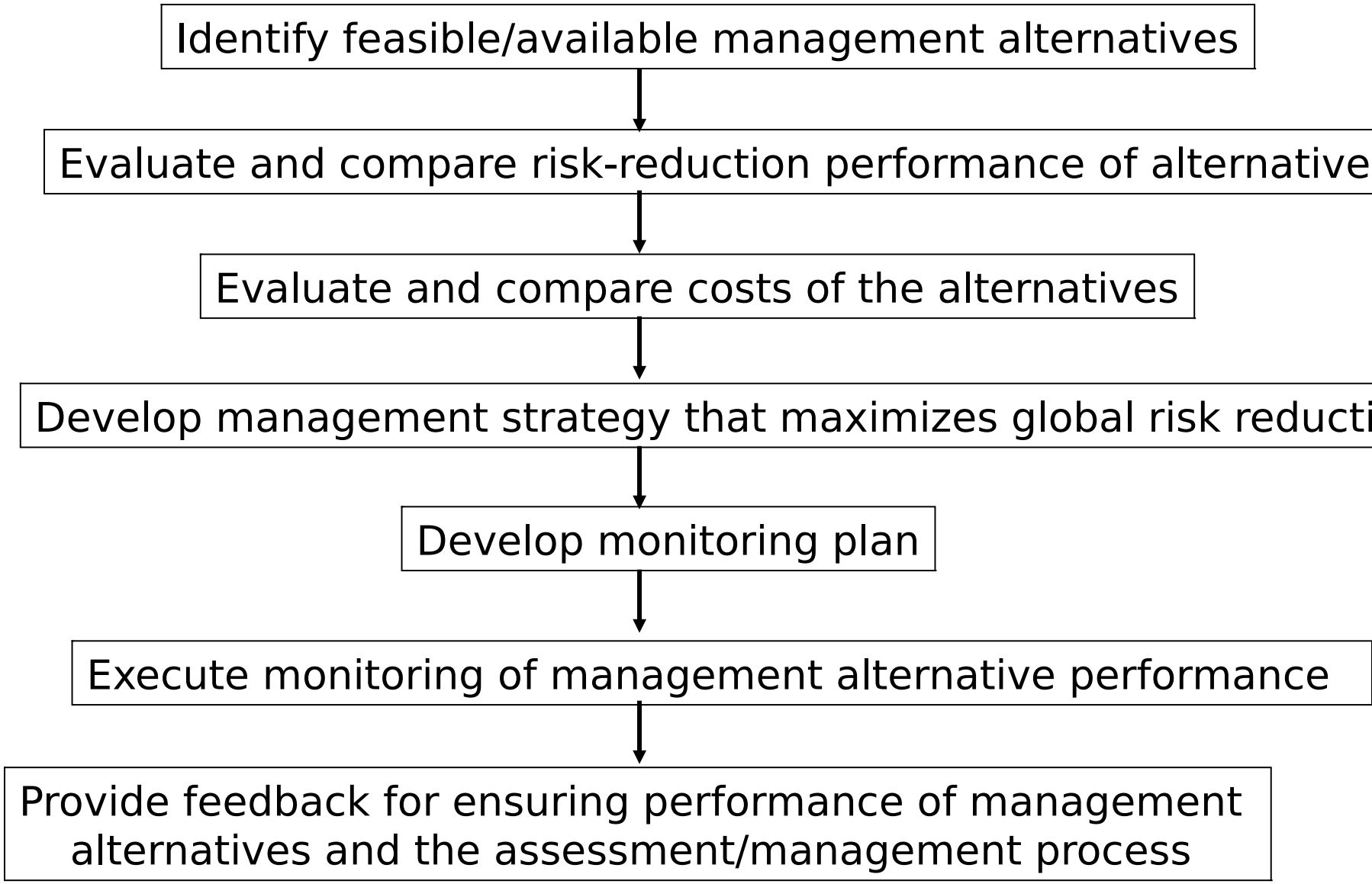
Scaling Level of Effort

- Need to scale the scope of any analysis to the needs of decision making
  - Tiered approach to risk assessment
    - Where sequential tiers represent growing investment in the analysis
    - Proceeding through tiers results in less uncertainty in the conclusions

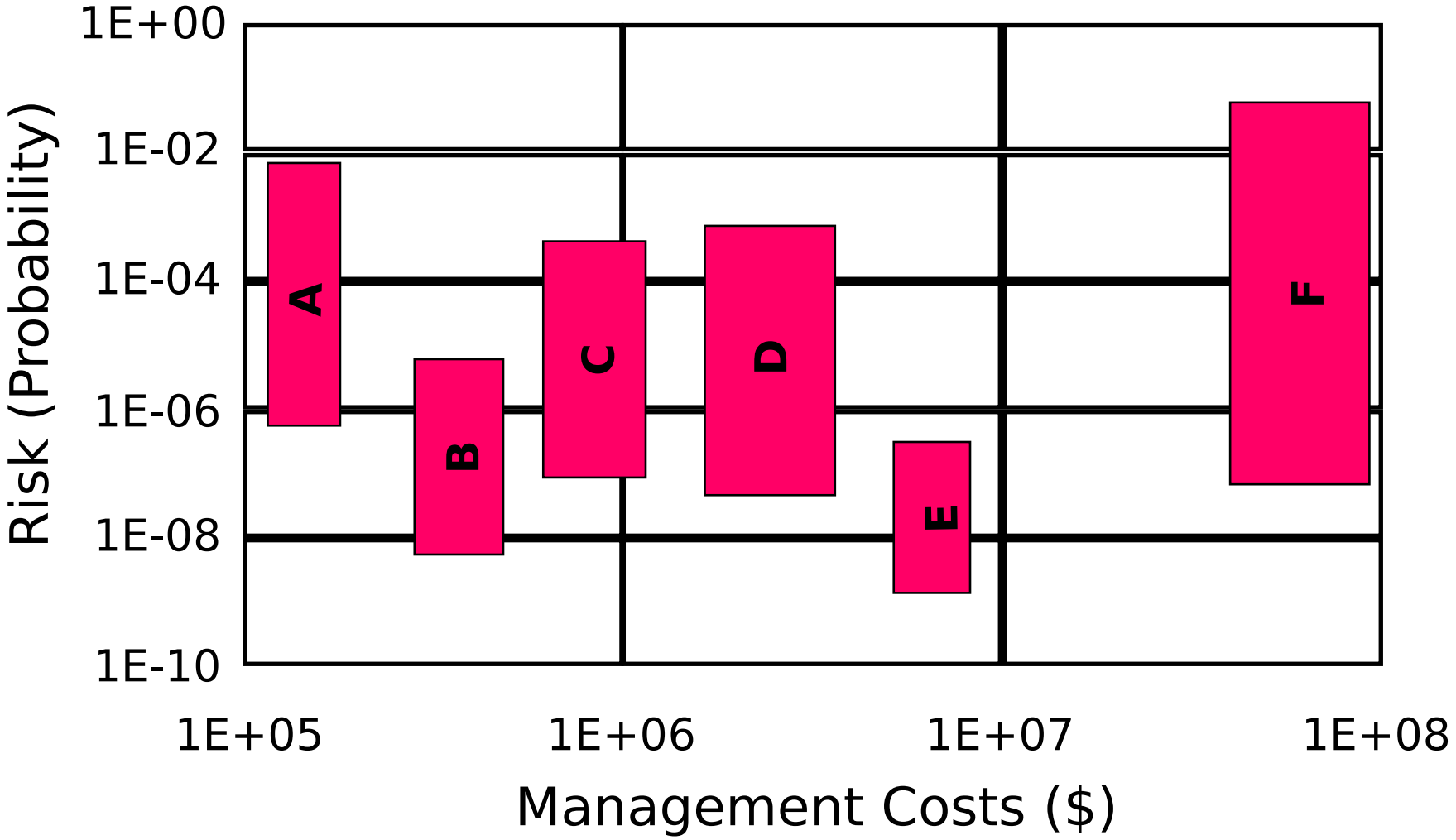
Assessment and Ranking of Risks


Comprehensive, but qualitative
Develop a list of potential threats and vulnerabilities
Qualitative to semi-quantitative
Rank risks in terms of potential costs (e.g., $, injuries, fatalities, lost opportunities) and time scales over which risks occur
Semi-quantitative to quantitative
Detailed analysis of ranked risks in order of ranking
Integrative
Integration of risk analyses to identify shared attributes, common variables, and risk synergies. Re-order ranking accordingly

Evaluating and Selecting Risk Management Alternatives


Identify feasible/available management alternatives
Evaluate and compare risk-reduction performance of alternative
Evaluate and compare costs of the alternatives
Develop management strategy that maximizes global risk reducti
Develop monitoring plan
Execute monitoring of management alternative performance
Provide feedback for ensuring performance of management alternatives and the assessment/management process

Risk-Based Decision Making



Relationship of CI to Risk

- “A CI is a quantitative rating between 0 and 100 that estimates the physical condition, as a snapshot in time, of a structure or structural component.” Foltz et al., 2001
  - A snapshot provides a limited view on potential future events or scenarios
    - Such projections are the objective of risk assessment

How to Address Uncertainty in CI?

- “The inspection procedures were to be objective measures targeted for completion by technicians and non-expert engineers. A criterion of the inspection procedures was that resulting CIs varied less than 10 points between various inspectors assessing a particular structure.” (Foltz et al., 2001)
  - Variation among inspectors is not the only source of uncertainty

Table 1. U.S. Army Corps of Engineers REMR condition indexing scale.

Zone	Condition Index	Condition Description	Recommended Action
1	85 to 100	**Excellent**: No noticeable defects. Some aging or wear may be visible.	Immediate action is not required.
	70 to 84	**Good**: Only minor deterioration or defects are evident.	
2	55 to 69	**Fair**: Some deterioration or defects are evident, but function is not significantly affected.	Economic analysis of repair alternatives is recommended to determine appropriate action.
	40 to 54	**Marginal**: Moderate deterioration. Function is still adequate.	
3	25 to 39	**Poor**: Serious deterioration in at least some portions of the structure. Function is inadequate.	Detailed evaluation is required to determine the need for repair, rehabilitation, or reconstruction. Safety evaluation is recommended.
	10 to 24	**Very Poor**: Extensive deterioration. Barely functional.	
	0 to 9	**Failed**: No longer functions. General failure or complete failure of a major structural component.	

50.2

30.2

From Foltz et al., 2001

Assume 3 inspectors return CIs of 40, 49, and 31:

The estimated CI is 40±10.2 at a confidence level of 95%

Risk and Reliability Analysis

- In a risk or reliability analysis, probabilistic analyses are performed to determine failure and consequence likelihoods
  - Approach is distributional
  - There is a temporal or predictive component that is not developed within CI
  - Demands much more data
- Can advancements be made to “tier” CI and R&R analyses used by the Corps?

OMB's Proposed Risk Assessment Bulletin

- Released for public comment January 9, 2006
  - Comment period closed June 15, 2006
- Purpose:
  - "…to enhance the technical quality and objectivity of risk assessments prepared by federal agencies by establishing uniform, minimum standards."
- *Risk assessment* defined*: "*a document that assembles and synthesizes scientific information to determine whether a potential hazard exists and/or the extent of possible risk to human health, safety or the environment."
  - "…this definition applies to documents that could be used for risk assessment purposes."

OMB's Proposed Risk Assessment Bulletin

- "The increasing importance of risk assessment in the development of public policy, regulation, and decision making requires that the technical quality and transparency of agency risk assessments meet high quality standards."
- "…this Bulletin will need to be updated periodically as agency practices and the peer-reviewed literature on risk assessment progress."
  - Corps practices will need to evolve with time as the practice of risk assessment advances

OMB's Proposed Risk Assessment Bulletin

- Uses of Risk Assessment
  - Priority setting
  - Informing Risk Management Decisions
    - Should risk be reduced? How?
  - Informing the Public

OMB's Proposed Risk Assessment Bulletin

- Types of Risk Assessments
  - Actuarial Analysis of Real-World Human Data
  - Dose-Response Analysis Using Experimental Data
  - Infectious Disease and Epidemic Modeling
  - Failure Analysis of Physical Structures
    - "Engineers have developed alternative techniques (e.g., fault-tree analysis) that estimate both the probability of catastrophic events and the magnitude of the resulting damages to people, property and the environment."

OMB's Proposed Risk Assessment Bulletin

- Five aspirational goals for RAs
  - Problem formulation
    - RA scope defined by dialogue between analysts and decision makers
  - Completeness
    - Balance between scientific completeness and relevance for decision making
  - Effort expended
    - Scaled to need, e.g., tier 1, 2, 3 risk assessment
  - Resources expended
    - Scaled to the importance of the RA
  - Peer review and public participation
    - Important

OMB's General Risk Assessment and Reporting Standards

Each agency risk assessment shall:

1. Provide a clear statement of the informational needs of decision makers, including the objectives of the risk assessment.
2. Clearly summarize the scope of the assessment, including a description of:
   - The agent, technology and/or activity that is the subject of the assessment;
   - The hazard of concern;
   - The affected entities (population(s), subpopulation(s), individuals, natural resources, ecosystems, or other) that are the subject of the assessment;
   - The event scenarios relevant to the objectives of the assessment; and
   - The type of event-consequence relationships for the hazard of concern.

OMB's General Risk Assessment and Reporting Standards

Each agency risk assessment shall:

3. Provide a characterization of risk, qualitatively and, whenever possible, quantitatively. When a quantitative characterization of risk is provided, a range of plausible risk estimates shall be provided.
4. Be scientifically objective:
   - As a matter of substance, neither minimizing nor exaggerating the nature and magnitude of risks;
   - Giving weight to both positive and negative studies in light of each study's technical quality; and
   - As a matter of presentation:
     - Presenting the information about risk in an accurate, clear, complete and unbiased manner; and
     - Describing the data, methods, and assumptions used in the assessment with a high degree of transparency.

OMB's General Risk Assessment and Reporting Standards

Each agency risk assessment shall:

5. For critical assumptions in the assessment, include a quantitative evaluation of reasonable alternative assumptions and their implications for the key findings of the assessment.
6. Provide an executive summary including:
   - Key elements of the assessment's objectives and scope;
   - Key findings;
   - Key scientific limitations and uncertainties and, whenever possible, their quantitative implications; and
   - Information that places the risk in context/perspective with other risks familiar to the target audience.

OMB's General Risk Assessment and Reporting Standards

Each agency risk assessment shall:

7. For risk assessments that will be used for regulatory analysis, the risk assessment also shall include:
   - An evaluation of alternative options, clearly establishing the baseline risk as well as the risk reduction alternatives that will be evaluated;
   - A comparison of the baseline risk against the risk associated with the alternative mitigation measures being considered, and assess, to the extent feasible, countervailing risks caused by alternative mitigation measures;
   - Information on the timing of exposure and the onset of the adverse effect(s), as well as the timing of control measures and the reduction or cessation of adverse effects;
   - Estimates of population risk when estimates of individual risk are developed; and
   - Whenever possible, a range of plausible risk estimates, including central or expected estimates, when a quantitative characterization of risk is made available.

OMB's Special Standards for Influential Risk Assessments

An Influential Risk Assessment: "a risk assessment the agency reasonably can determine will have or does have a clear and substantial impact on important public policies or private sector decisions"

All influential agency risk assessments shall:

1. Be "capable of being substantially reproduced" as defined in the OMB Information Quality Guidelines.
2. Compare the results of the assessment to other results published on the same topic from qualified scientific organizations.
3. Highlight central estimates as well as high-end and low-end estimates of risk when such estimates are uncertain.

OMB's Special Standards for Influential Risk Assessments

All influential agency risk assessments shall:

4. Characterize uncertainty with respect to the major findings of the assessment including:
   - Document and disclose the nature and quantitative implications of model uncertainty; and where feasible:
   - Include a sensitivity analysis; and
   - Provide a quantitative distribution of the uncertainty.
5. Portray how choice among effects and/or studies used influences the assessment.
6. Characterize, to the extent feasible, variability through a quantitative distribution, reflecting different affected population(s), time scales, geography, or other parameters relevant to the needs and objectives of the assessment.

OMB’s Special Standards for Influential Risk Assessments

All influential agency risk assessments shall:

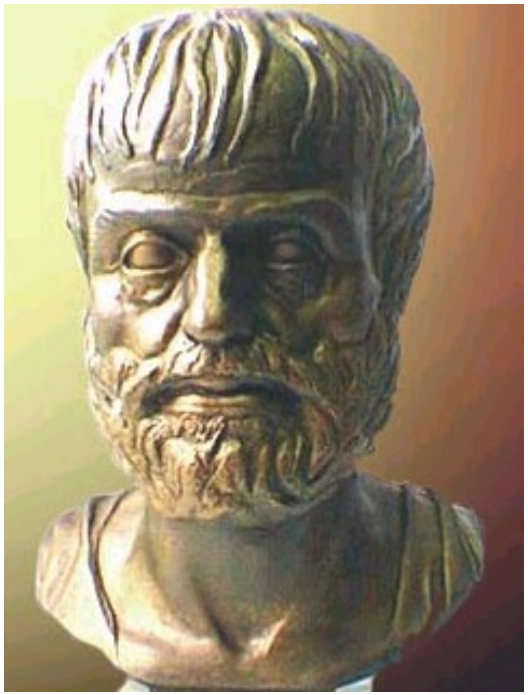
7. Where human health effects are a concern, determination of effects will be based on the best available scientific information.
8. Provide discussion, to the extent possible, of the nature, difficulty, feasibility, cost and time associated with undertaking research to resolve a report's key scientific limitations and uncertainties.
9. Consider all significant comments received on a draft risk assessment report and:
   - Issue a "response-to-comment" document; and
   - Provide a rationale for why the agency has not adopted the position suggested by commenters and why the agency position is preferable.

OMB's Proposed Risk Assessment Bulletin

- Certification
  - "For each risk assessment subject to this Bulletin, the agency shall include a certification explaining that the agency has complied with the requirements of this Bulletin and the applicable Information Quality Guidelines…"

Timeless Truth of Risk Assessment

“It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject permits and not to seek an exactness where only an approximation of the truth is possible.”



Aristotle